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The Breakfast Meal in Relation to Blood-Sugar Values

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The Breakfast Meal in Relation to Blood-Sugar Values[1]

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INTRODUCTION

Recent surveys have shown that many people in this country either omit breakfast entirely or eat what most authorities would consider nutritionally inadequate morning meals. Recommendations for improving diets by means of the breakfast meal have been based chiefly on theoretical grounds. Few attempts have been made to observe the effect of different types and sizes of meals on the physiological reactions of human subjects.

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REVIEW OF LITERATURE

The earliest study of the effect of breakfast on physiological processes probably was that reported in 1924 by Bauer and Blunt (*3*)[3] of the effect of a small breakfast on the energy metabolism of children. The most recent reports include those of Tuttle, Wilson, and Daum (*32*) on the effect of altered breakfast habits on physiological response, and of Leverton and Gram (*21*, *22*) on the effect upon nitrogen retention of the distribution of the protein-rich foods of animal origin among the three meals of the day.

Bauer and Blunt observed in a study of seven children that the average consumption of oxygen 4 hours after breakfast was only 0.6 percent higher than that measured before the meal. They found no differences that could be attributed to the type of breakfast, although the breakfasts ranged in calorie value from 200 to 470 and in protein from 3 to 13.8 gm.

Tuttle and coworkers made a study of the effect of altered breakfast habits on maximum work output, reaction time in responding to simple situations and those involving choice, and neuromuscular tremor. The breakfasts used consisted of coffee with cream only; a 400-calorie meal composed of fruit, toast, butter, milk, and coffee; and an 800-calorie meal of fruit, cereal, cream, egg, bacon, toast, jam, milk, and coffee. Effect of omission of breakfast was also studied. Although considerable individual differences in response to altered breakfast habits were found, having no breakfast and having only coffee in the morning tended to cause a decrease in the maximum work output and an increase in tremor magnitude. Improvement in these physiological responses was noticed after consumption of the breakfast meals.

Leverton and Gram (*22*) found increased nitrogen utilization among 14 college girls receiving diets that provided fully the recommended allowances of protein, minerals, and vitamins during the day, when the high quality protein was distributed in all three of the day's meals rather than in only the noon and evening meals. Even though the day's protein intake was the same during both experimental periods, there was a tendency among the subjects to use more of the nitrogen available when, of the day's quota of three glasses of milk, one of the two glasses first served in the evening meal was transferred to be part of the breakfast. Breakfast had first consisted of fruit, bread products made without milk, and coffee.

A limited number of studies, in most cases with clinical patients rather than individuals in good health, suggest that the nutritive quality of the breakfast rather than the quantity of food eaten for breakfast is a predisposing cause for the symptoms characteristic of midmorning fatigue. Meals high in carbohydrate and usually relatively low in thiamine have been said to produce these symptoms.

Functional hypoglycemia which, in its milder form, is believed by some to be a fairly common occurrence among those who eat very little or no food at all for a considerable length of time, gives rise to such symptoms as a sense of weakness, fatigue, and inability to concentrate. In the treatment of this type of hypoglycemia, improvement has been achieved by reducing the carbohydrate intake and increasing the intake of protein and fat.

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[3] Italicized figures in parentheses refer to Literature Cited, p. 23.

Haldi and Wynn (*15*) reporting in 1946, found no appreciable differences in blood-sugar level nor any symptoms of hypoglycemia following two types of breakfast which provided, respectively, food energy of 400 and 600 calories; protein, 21 and 22, and 13 and 18 gm.; and fat, 2 and 3 gm. On the other hand, Conway (*12*), comparing the blood-sugar levels of 14 college women after two breakfasts, one containing 67 gm. of carbohydrate, 13 of fat, and 5 of protein (407 calories), and the other having 34 gm. of carbohydrate, 15 of fat, and 25 of protein (362 calories), found that the high carbohydrate-low protein meal was followed by a hypoglycemic lag between the second and third hours, accompanied by feelings of hunger. She also found that a more constant blood-sugar level was maintained after a breakfast containing relatively high amounts of protein.

In the treatment of individuals with spontaneous hypoglycemia, the advantage of employing diets high in protein has been pointed out by Waters (*34*), Clark and Greene (*8*), Conn (*9*), Swanson and Greene (*29*), and Conn and Newburgh (*11*). Complete relief from hypoglycemic symptoms was reported by Sevringhaus in 1947 in a discussion of a paper by Conn on the dietary management of hypoglycemia (*10, pp. 137–138*). Sevringhaus described a case of an individual who for many years consistently ate a breakfast of fruit, dry cereal with milk and sugar, large quantities of toast, and coffee. Between 10:30 a. m. and 1:30 p. m. this individual consistently experienced marked discomfort, hunger, and nervousness which were diagnosed as hypoglycemia. Reduction of the intake of toast, elimination of the cereal and substitution of bacon and eggs resulted in complete relief from the symptoms. Thorn and coworkers (*31*) also reported that no symptoms of hypoglycemia followed ingestion of a breakfast high in protein and low in carbohydrate and fat.

PLAN OF PRESENT STUDY

In 1946 when this study was begun, there were in the literature few data on the biochemical responses of normal active individuals to breakfasts typical in this country or breakfasts such as are currently recommended in educational programs.

The study here reported was undertaken to add to our knowledge of the effect of the composition of the breakfast meal upon the carbohydrate-thiamine metabolism of man and its relation to the feeling of general well-being of the individual. This research has been chiefly concerned with the effect of each of a series of eight controlled breakfast meals on carbohydrate metabolism as measured by the rate at which glucose enters and is removed from the blood stream. Fasting blood-sugar levels and meal-tolerance tests were made over a period of 3 hours after each breakfast and in some cases also after lunch. Urinary excretion of thiamine and pyruvic acid was also determined at appropriate intervals.

Preliminary to this work an exploratory study was made of the urinary excretion values for thiamine and pyruvic acid of apparently normal adults consuming customary self-selected breakfasts. The subjects volunteering for this phase were laboratory workers (15 women and 3 men) ranging in age from 25 to 50 years, whose dietary habits and physical activities were typical of those who were to serve as subjects in the main study. For a 3-day testing period, all ate their customary and entirely self-selected diet and recorded their food intake on record sheets provided for the purpose. Urine samples were collected covering a 3-hour period after breakfast.

Of the aggregate 54 breakfasts that normally would have been eaten by these 18 subjects, 11 meals were missed entirely. Of the 43 meals consumed, 32 included citrus fruit juice; 8, a breakfast cereal; 11, milk to drink; 24, eggs or meat; 34, bread in some form; 33, butter, table fat, or cream; and 21, sugar.

In the urine formed during the 3-hour period immediately following breakfast, the values for pyruvic acid for most subjects ranged from 0.5 to 2.3 mg., and for thiamine from 10 to 50 mg. One subject gave extremely high values, another very low.

The main phase of the research was concerned, as stated earlier, with a study of breakfasts controlled by quantity and kind of food in relation to blood-sugar levels, and urinary thiamine and pyruvic acid.

General Procedure

The experimental studies were preceded by a standardization period of 3 weeks during which all of the subjects ate the same meals (breakfast No. 8, lunch No. 1, and dinner No. 1 (table 1)). During this period, the subjects became accustomed to the various procedures used for obtaining the materials for biochemical study.

In studies concerned with breakfasts No. 1, 2, 3, and 8, two types of biochemical data were obtained—blood glucose, urinary thiamine, and pyruvic acid. Creatinine was determined to assure complete collection of urine. (Though not reported, specific gravity of the urine was also determined to ascertain that all subjects were within the normal range in this respect.)

Fasting blood sugar and the change in blood-sugar levels following the ingestion of each of these breakfasts were determined on the first day of each set of experiments. Lunch, dinner, and also breakfast on a second day were controlled. During each experiment, three samples of urine were collected from each subject. The first was that formed during the 3-hour period immediately following the first day's experimental breakfast; the second included that formed during the 21 hours from lunch until just before breakfast on the second day; and the third sample was that formed on the second day during 3 hours after the eating of the experimental breakfast.

In addition to determining blood-sugar levels in the course of the morning following breakfasts No. 1, 2, 3, and 8, blood-sugar levels were determined on the same day during a 4-hour period following the ingestion of an identical midday meal (luncheon No. 1).

In studies concerned with breakfasts No. 4, 5, 6, and 7, determinations were made only of fasting blood sugar and changes in the blood-glucose concentrations during the 3-hour period immediately following the ingestion of the meals.

Experimental Meals

Included in the investigations were eight different food combinations commonly served for breakfast and providing varying quantities of protein and food energy. One breakfast consisted of unsweetened black coffee only; a second, coffee and doughnuts; a third, citrus juice, bacon, toast with butter and preserves, coffee with cream and sugar. The other breakfasts consisted of the last-named combination with or without preserves, and with the addition of (a) breakfast cereals and milk; (b) eggs; or (c) milk. The quantities of food in these latter combinations were adjusted to make them either equi-caloric or equal in protein with the same or larger calorie value (table 1).

The meal consisting of doughnuts and black coffee, breakfast No. 2, supplied less than one-third of the daily food energy and other essential nutrients. Breakfast No. 3 provided fewer calories than breakfast No. 2. It furnished more of the essential nutrients but still did not meet nutritional recommendations. Breakfasts No. 4, 5, 6, and 7 are practically isocaloric. Meals No. 4 and 5 include a hot cooked breakfast cereal and a cold ready-to-eat one, respectively. Breakfasts No. 6 and 7 are very similar in content of protein, fat, and carbohydrate, with their protein derived largely from milk and eggs, respectively. Breakfast No. 8 was identical with breakfast No. 7 except that it included additional buttered toast and preserves.

In breakfast No. 6, fluid whole milk was combined with nonfat dry milk solids so that the volume needed to provide the planned quantity of protein did not necessitate the consumption of more fluid at one meal than is acceptable to most individuals. The milk beverage was prepared by thoroughly mixing homogenized milk with the nonfat dry milk in a Waring blendor. It was usually prepared on the afternoon preceding use. The subjects considered this milk beverage highly acceptable.

With breakfasts No. 1, 2, 3, and 8, standardized luncheon and dinner meals were also served. Two sets of meals were used (table 1). One was composed of generous quantities of relatively expensive foods and the other of low-cost food combinations, more restricted in calories, fat, and protein.

All meals were prepared and cooked by usual household methods in the laboratory kitchen, and were served attractively at regular hours in a pleasant small dining room. They were well accepted by the subjects as a rule. While at no time was food rejected, the subjects expressed themselves as feeling uncomfortably full following breakfasts including cereal, especially so following the breakfast which contained oatmeal. This may be due, at least in part, to the fact that these persons were not accustomed to morning meals including breakfast cereal.

Throughout the experimental periods, the subjects ate only the diet supplied and did not take any vitamin or other supplements.

TABLE 1.—*Composition of controlled meals used in experimental periods*

Menus and food items	Quantity served	Composition of meals[1]				
		Protein	Fat	Carbohydrate	Thiamine[2]	Food energy
Breakfast No. 1:		*Gm.*	*Gm.*	*Gm.*	*Mg.*	*Cal.*
Black coffee (no sugar)	1 cup					
Breakfast No. 2:						
Doughnuts, plain	2	7	20	50	0. 026	400
Black coffee (no sugar)	1 to 2 cups					
Breakfast No. 3:						
Citrus juice, unsweetened	½ cup	9	15	48	. 179	359
Bacon, broiled	2 strips					
Bread, enriched white, toasted	1 slice					
Butter	½ square					
Preserves	1 tablespoon					
Coffee	1 to 2 cups					
Cream, light	2 tablespoons					
Sugar	2 teaspoons					
Breakfast No. 4:						
Breakfast No. 3 *without* preserves, *plus:*						
Cooked oatmeal	¾ cup	16	21	66	. 589	519
Sugar	3 teaspoons					
Milk, whole fluid	½ cup					
Breakfast No. 5:						
Breakfast No. 3 *without* preserves, *plus:*						
Wheat flakes (prepared dry)	¾ cup	17	20	67	. 539	515
Sugar	1 teaspoon					
Milk, whole fluid	½ cup					
Breakfast No. 6:						
Breakfast No. 3 *without* preserves, *plus:*						
Milk, whole fluid	8 ounces	22	24	51	. 415	511
Milk, nonfat dry solids	1 ounce					
Breakfast No. 7:						
Breakfast No. 3 *plus:*						
Eggs, boiled	2	22	27	48	. 254	519
Breakfast No. 8:						
Breakfast No. 7 *plus:*						
Bread, enriched, white, toasted.	1 slice	25	40	75	. 335	758
Butter	1½ squares					
Preserves	1 tablespoon					

See footnotes at end of table.

TABLE 1.—*Composition of controlled meals used in experimental periods*—Continued

Menus and food items	Quantity served	Composition of meals [1]				
		Protein	Fat	Carbohydrate	Thiamine [2]	Food energy
Luncheon No. 1:						
Sandwich (1), made of:		*Gm.*	*Gm.*	*Gm.*	*Mg.*	*Cal.*
Bread, whole-wheat	2 slices	5	17	32	0. 135	304
Tomato	2 slices					
Lettuce	2 leaves					
Mayonnaise	1 tablespoon					
Coffee, black	1 or more cups					
Luncheon No. 2:						
Cream of mushroom soup	¾ cup	16	17	121	. 234	705
Crackers	3					
Waldorf salad	¾ cup					
Date-nut bread with Philadelphia cream cheese.	2 slices					
Tea, without sugar or milk	1 or more cups					
Dinner No. 1:						
Frankfurters	2	36	40	74	. 314	797
Beans, baked	½ cup					
Catsup	1 tablespoon					
Lettuce	¼ head					
French dressing	2 teaspoons					
Carrot sticks, raw	½ cup					
Bread	1 slice					
Butter	1 square					
Peaches, canned in sirup	2 halves					
Tea, without sugar or milk	1 cup					
Dinner No. 2:						
Tomato juice	½ cup	130	42	126	1. 396	1, 406
Steak, broiled	½ pound					
Potato, baked	1					
Peas	½ cup					
Salad consisting of:						
Lettuce	3 leaves					
Tomato	2 slices					
French dressing	2 teaspoons					
Roll	1					
Butter	2 squares					
Peaches, frozen	½ cup					
Cookies	2					
Tea, without sugar or milk	1 cup					
Apple (eaten in evening)	1					

See footnotes at end of table.

TABLE 1.—*Composition of controlled meals used in experimental periods*—Continued

Menus and food items	Quantity served	Composition of meals [1]				
		Protein	Fat	Carbohydrate	Thiamine [2]	Food energy
		Gm.	*Gm.*	*Gm.*	*Mg.*	*Cal.*
Breakfast No. 1, plus lunch No. 1 and dinner No. 1.	--------------	41	57	106	0. 442	1, 101
Breakfast No. 2, plus lunch No. 1 and dinner No. 1.	--------------	48	76	156	. 478	1, 501
Breakfast No. 3, plus lunch No. 1 and dinner No. 1.	--------------	50	72	154	. 621	1, 460
Breakfast No. 8, plus lunch No. 1 and dinner No. 1.	--------------	65	97	181	. 775	1, 859
Breakfast No. 3, plus lunch No. 2 and dinner No. 2.	--------------	155	74	295	1. 809	2, 470
Breakfast No. 8, plus lunch No. 2 and dinner No. 2.	--------------	170	99	322	1. 966	2, 869

[1] Except as noted, calculated from tables of average food composition (*6, 7, 30, 33*).

[2] By direct assay.

SUBJECTS STUDIED

Nine women laboratory workers, ranging in age from 28 to 48 years, volunteered to serve as subjects. They were of average height and weight, were doing moderately active work in the laboratory, appeared to be in good health, and reported a sense of physical fitness. By coincidence, none were smokers. Their hemoglobin, red-cell, and white-cell blood counts were normal (table 2). The urinary specific gravity and creatinine values were also within the normal ranges. No urinary glucose was detected after breakfast.

Six or seven individuals were used in the study of each breakfast and each breakfast was tested at three separate periods on every subject. None of the subjects participated in an experiment when suffering from a cold, or during a menstrual period.

TABLE 2.—*Hematic values of 6 subjects fed controlled breakfasts*

Subject	Hemoglobin		Red blood cells	White blood cells
	Gm./100 ml.	*Percent*	*Per mm.*^{3}	*Per mm.*^{3}
CL-------------------------	13. 5	88	4, 230, 000	6, 450
GE-------------------------	14. 0	95	4, 630, 000	8, 350
UR-------------------------	14. 0	95	4, 980, 000	9, 050
AD-------------------------	14. 0	95	4, 990, 000	5, 750
HL-------------------------	15. 0	100	4, 800, 000	6, 000
WM-------------------------	13. 0	90	4, 320, 000	8, 700

ANALYTICAL METHODS

MEALS

With the exception of thiamine, the composition of the meals was calculated from tables of food composition (*6*, *7*, *30*, *33*). Actual analyses of thiamine were made, at intervals, on individual breakfast, luncheon, and dinner meals which were duplicates of those prepared for serving the subjects.

The entire meal was weighed, cooled, and thoroughly macerated in a Waring blendor; the mixture was adjusted to pH 4.0 by adding concentrated HCl dropwise. The blended material was then placed in a waxed carton, quick-frozen, and stored at —40° C. until analyzed. At this time, the frozen sample was thawed at room temperature for about 2 hours, and again mixed thoroughly in the Waring blendor. Six aliquots of the mixture were withdrawn and weighed; known amounts of pure thiamine solution were added to three of the aliquots for measuring recovery of the vitamin. Hydrochloric acid, 0.6N, was added and the aliquots were digested on a steam bath for about 30 minutes. The samples were incubated with 5-percent "Polidase-S" in buffer solution at 37° C. overnight, about 16 hours. They were then filtered, and the filtrates were made up to 250 ml.; aliquots were used for the thiochrome determination.

BLOOD

SUGAR.—Folin's micro method (*13*) was followed, except that instead of the sodium cyanide-sodium carbonate solution, 1.6 percent sodium carbonate was used (*20*). Blood from a finger prick was collected into a paraffin well. The same 0.1 ml. pipette was used throughout the day for each individual. All measurements and readings throughout the study were made by the same analyst. Readings were made on a Beckman spectrophotometer at 5200 Å. Time was measured from the beginning of eating breakfast; variation from the theoretical time was not greater than ±2 minutes. Periodic standard glucose curves were made to check the reagents and the instrument.

HEMOGLOBIN.—The Sahli hemoglobinometer was used to measure the hemoglobin content of the blood.

RED AND WHITE BLOOD COUNT.—The blood-cell counts were made by use of standard dilution pipettes, diluting fluid, and hemocytometers.

URINE

SPECIFIC GRAVITY.—This was measured by hydrometer.

CREATININE.—Micro modification of Folin's method (*1*) was used.

THIAMINE.—The thiochrome procedure of Mickelsen, Condiff, and Keys (*25*) was used with a Lumetron spectrophotometer, model No. 402ED.

PYRUVIC ACID.—The method of Friedemann and Haugen (*14*) was used with a Beckman spectrophotometer at 4400 Å.

ACETONE.—The nitroprusside test (*16, p. 773*) was followed.

GLUCOSE.—Benedict's test (*4*) was used.

TABLE 3.—*Seasonal variation in fasting blood sugars (mg./100 ml.)* [1]

Subject	January	February	March	April	May	June	July	August	September	October	November
AD	95	93	96	86	----	72	74	----	100	99	----
	----	----	112	97	----	88	77	----	85	107	----
	----	----	----	----	----	74	----	----	----	105	----
	----	----	----	----	----	87	----	----	----	100	----
	----	----	----	----	----	63	----	----	----	----	----
	----	----	----	----	----	77	----	----	----	----	----
	----	----	----	----	----	73	----	----	----	----	----
	----	----	----	----	----	79	----	----	----	----	----
	----	----	----	----	----	84	----	----	----	----	----
	----	----	----	----	----	75	----	----	----	----	----
CE	----	----	----	----	80	89	----	----	----	107	101
	----	----	----	----	88	78	----	----	----	88	----
	----	----	----	----	----	82	----	----	----	111	----
	----	----	----	----	----	82	----	----	----	98	----
	----	----	----	----	----	80	----	----	----	98	----
	----	----	----	----	----	80	----	----	----	----	----
CL	85	91	92	80	75	65	58	----	83	95	----
	----	----	83	86	79	76	67	----	76	75	----
	----	----	83	----	----	70	----	----	----	80	----
	----	----	----	----	----	65	----	----	----	98	----
	----	----	----	----	----	77	----	----	----	----	----
	----	----	----	----	----	72	----	----	----	----	----
	----	----	----	----	----	60	----	----	----	----	----
	----	----	----	----	----	70	----	----	----	----	----
GE	103	----	102	100	----	75	74	----	----	----	----
	----	----	----	88	----	66	74	----	----	----	----
	----	----	----	101	----	63	----	----	----	----	----
	----	----	----	----	----	63	----	----	----	----	----
HL	91	98	97	97	77	60	60	----	95	95	----
	90	----	115	96	92	97	74	----	----	91	----
	----	----	----	----	----	70	70	----	----	94	----
	----	----	----	----	----	76	----	----	----	96	----
	----	----	----	----	----	62	----	----	----	94	----
	----	----	----	----	----	83	----	----	----	----	----
	----	----	----	----	----	74	----	----	----	----	----
KE	----	----	----	----	81	95	----	----	101	108	----
	----	----	----	----	88	77	----	----	96	107	----
	----	----	----	----	86	76	----	----	85	98	----
	----	----	----	----	----	74	----	----	----	----	----
	----	----	----	----	----	82	----	----	----	----	----
TG	117	113	119	106	97	97	----	----	106	108	----
	----	----	119	117	105	83	----	----	100	107	----
	----	----	130	----	----	101	----	----	----	118	----
	----	----	----	----	----	95	----	----	----	114	----
UR	86	93	83	84	----	67	65	----	----	----	----
	----	83	----	91	----	66	62	----	----	----	----
	----	----	----	88	----	56	56	----	----	----	----
WM	94	98	102	99	86	63	65	----	99	91	----
	----	----	93	93	97	87	69	----	----	88	----
	----	----	99	----	----	60	78	----	----	91	----
	----	----	----	----	----	85	----	----	----	89	----
	----	----	----	----	----	74	----	----	----	88	----
	----	----	----	----	----	79	----	----	----	----	----
	----	----	----	----	----	83	----	----	----	----	----
Average	95	96	102	94	87	76	68	----	93	98	----

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[1] These data were obtained during a period of 2 years.

RESULTS AND DISCUSSION

Fasting Blood-Sugar Levels in Relation to Season

During the course of the 2-year experimentation, highly significant seasonal differences were found in fasting blood-sugar levels. Although all of the values were within the range of those given by Peters and Van Slyke (*26, pp. 155–295*), the figures for the individuals studied tended to be significantly higher in the winter months than during the summer (table 3, fig. 1). A search of the literature revealed only two observations (*19; 28, p. 758*) which suggest the occurrence of such a phenomenon.

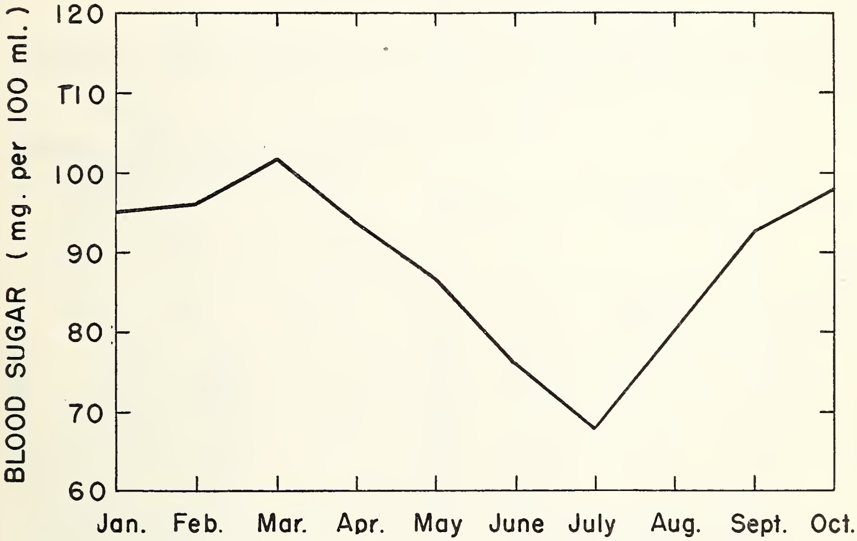

FIGURE 1.—Seasonal variation in fasting blood sugar of nine women.

Blood-Sugar Levels in Relation to Breakfasts

Because of the difference in the base line due to the season in which various experiments were conducted, comparisons among breakfasts are made in terms of changes in blood-sugar levels (table 4 and fig. 2) as compared with fasting levels.

When breakfast consisted of unsweetened black coffee only (breakfast No. 1), there was, as expected, no rise in the blood sugar above the fasting level, and a moderate, progressive descent below the fasting level occurred throughout the subsequent 3-hour period. At no time did the values fall to true hypoglycemic levels, but traces of acetone were detected in the urine of three out of the seven subjects. Following this breakfast, unfavorable subjective symptoms, including hunger, weakness, headache, and lassitude were often reported both on the first and the second morning of the test period.

Blood-sugar curves characteristic of the normal response to glucose ingestion were obtained after breakfast meals No. 2, 3, 4, and 5. There was a rapid rise from the fasting level during the first half hour after ingestion of food, followed by a fall to the original fasting level during the next 3 hours.

After breakfasts No. 6, 7, and 8, meals which contained from 22 to 25 gm. protein derived chiefly from milk or eggs, the postprandial rise in blood sugar was also normal. The average maximal level was lower (125 mg.), however, than the average following breakfasts 2, 3, 4, and 5 (134 mg.), and the return to the fasting level was delayed beyond the usual 3-hour period. At all times the blood-sugar concentration was within the normal range, and the subjects reported a prolonged sense of well-being and satisfaction.

TABLE 4.—*Average fasting blood-sugar level (mg./100 ml.) and change in specified periods after breakfast (3 experimental periods per subject)*

Meal, time of year, and subject	Fasting level	Change from fasting level (positive unless otherwise indicated) in specified period after breakfast			
		½ hour	1 hour	2 hours	3 hours
Breakfast No. 1 (April):					
CL	86	--------	−2	−1	2
UR	88	--------	3	−3	0
WM	93	--------	4	1	4
HL	96	--------	−2	−3	1
AD	97	--------	−3	−7	−7
GE	101	--------	−8	−8	−4
TG	117	--------	−2	−5	−16
Average	97	--------	−2	−4	−3
Breakfast No. 2 (January, February, March):					
CL	89	22	23	5	−3
UR	87	39	10	−2	2
WM	98	19	6	−1	−6
HL	93	41	19	19	5
AD	93	27	24	20	0
GE	103	7	−5	1	−3
TG	116	38	17	−9	−20
Average	97	28	12	5	−4
Breakfast No. 3 (May, June, July):					
CL	62	33	14	5	−2
UR	61	37	15	6	6
WM	71	41	3	2	−5
HL	68	38	22	7	3
AD	75	31	14	2	1
GE	70	36	5	11	5
KE	84	63	24	8	5
CE	84	83	30	−3	4
Average	72	45	16	5	2

TABLE 4.—*Average fasting blood-sugar level (mg./100 ml.) and change in specified periods after breakfast (3 experimental periods per subject)*—Continued

Meal, time of year, and subject	Fasting level	Change from fasting level (positive unless otherwise indicated) in specified period after breakfast			
		½ hour	1 hour	2 hours	3 hours
Breakfast No. 4 (September, October):					
CL	85	45	18	3	5
WM	89	51	16	15	14
HL	95	63	26	16	2
AD	97	44	16	16	7
TG	107	63	36	1	−10
KE	93	51	26	15	9
CE	102	75	24	4	−10
Average	95	57	24	10	1
Breakfast No. 5 (September, October):					
CL	84	51	29	22	9
WM	93	51	22	11	9
HL	93	56	17	12	12
AD	102	35	18	22	10
TG	111	64	33	16	−10
CE	99	77	46	10	−6
KE	105	38	32	14	9
Average	98	53	28	15	5
Breakfast No. 6 (May, June):					
CL	72	33	23	14	13
WM	86	62	5	3	14
HL	83	64	32	8	11
AD	84	34	14	17	15
TG	92	69	13	10	7
KE	84	54	30	14	8
CE	82	69	27	−3	6
Average	83	55	21	9	11
Breakfast No. 7 (May, June):					
CL	74	38	12	11	9
WM	86	38	1	13	10
HL	83	45	9	17	14
AD	79	54	16	15	17
TG	100	43	25	8	4
KE	79	46	17	23	14
CE	81	57	20	9	7
Average	83	46	15	14	11
Breakfast No. 8 (June):					
CL	71	15	7	3	−3
UR	63	50	9	10	11
WM	66	44	8	10	5
HL	64	44	15	18	16
AD	70	37	10	8	6
GE	68	28	8	10	9
Average	67	36	9	10	7

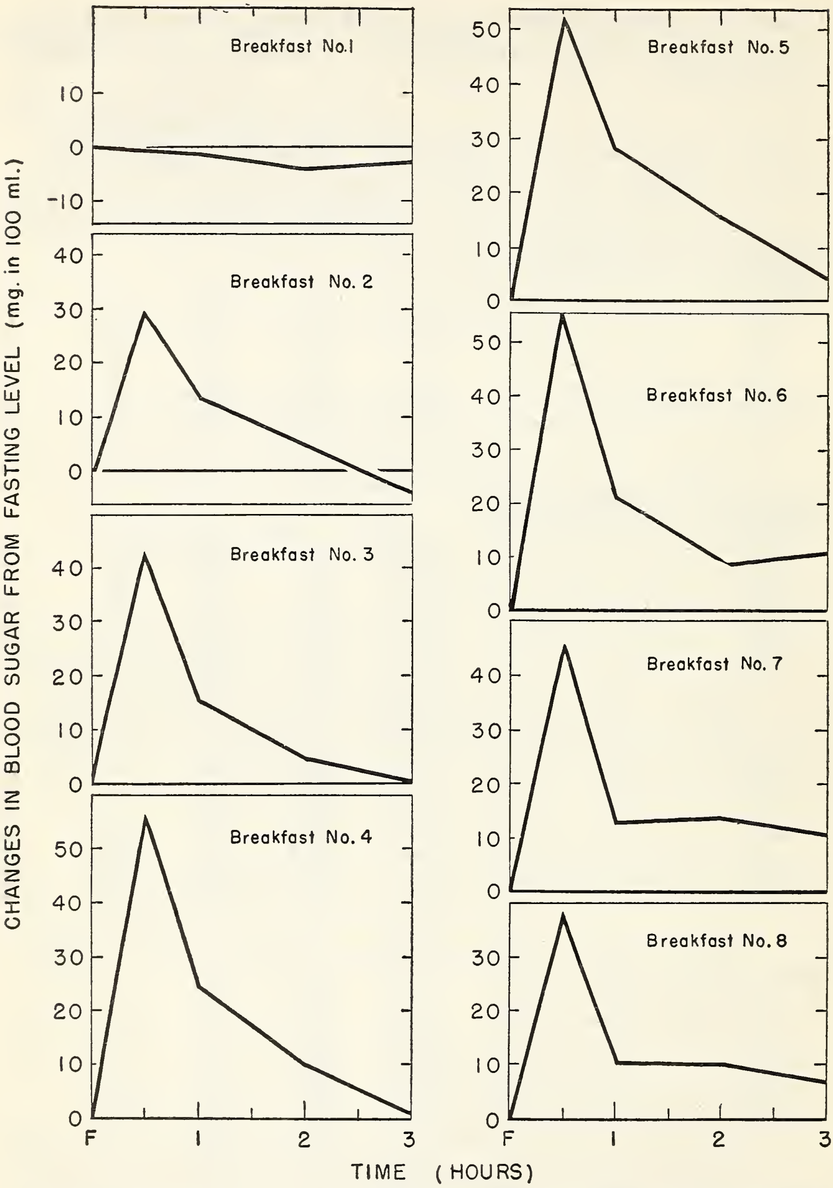

FIGURE 2.—Changes in blood sugar from fasting levels during 3 hours following ingestion of eight experimental breakfasts. Each curve is an average of three experiments with at least six individuals.

INFLUENCE OF BREAKFAST ON BLOOD-SUGAR LEVELS AFTER LUNCH

The influence of the breakfast meal on blood-sugar levels may extend into the afternoon, as shown in table 5 and figure 3. Thus following identical midday meals (luncheon No. 1), a lower maximal rise in blood sugar was observed together with a relatively more sustained sugar level during the course of the afternoon, when subjects had eaten breakfast No. 8 than when they had eaten breakfasts No. 1, 2, or 3. Subjective symptoms of hypoglycemia were reported after lunch following breakfast No. 1. These seemed to accompany the rapid drop in postluncheon blood-sugar levels (fig. 3).

URINARY EXCRETION OF PYRUVIC ACID

No differences were observed in the urinary excretion of pyruvic acid that were attributable to any of the breakfast meals so studied (table 6). The values were of the same order even when only unsweetened black coffee was taken, and values fluctuated in the same individuals from time to time independent of the intake of food in meals immediately preceding the tests.

URINARY EXCRETION OF THIAMINE

Throughout this study wide variations were observed in the urinary thiamine. However, this is to be expected. Mickelsen and coworkers demonstrated that urinary excretion of thiamine is not stabilized for at least 30 days on any constant dietary regime (*24*). These investigators and others (*5*) have observed that when equilibrium is finally established on a constant dietary intake, large individual differences and day-to-day variations still occur.

When breakfasts No. 1 and No. 2, lacking or very low in thiamine, were used in combination with lunch No. 1 and dinner No. 1, the day's total intake was below 0.5 mg. The thiamine values of the urine formed during the morning of the second experimental day reflected this low intake, with a drop of about 30 percent as compared with the 3-hour specimen of the first day (table 6). However, when breakfasts No. 3 and No. 8 were used in combination with the same noon and evening meals, the greater intake of thiamine at breakfast raised the day's total to well above 0.6 mg. and there was practically no difference between the thiamine values in the 3-hour urine samples for the 2 days. This was also true in the experiments in which breakfasts No. 3 and No. 8 were combined with lunch No. 2 and dinner No. 2, although the level of urinary thiamine was greater, inasmuch as the total day's intake was more than double that when these breakfasts were combined with luncheon and dinner No. 1.

TABLE 5.—*Average fasting blood-sugar levels (mg./100 ml.) and change in specified periods after different breakfasts and lunch No. 1, March and April*

Breakfast No. and subject	Fasting level	Change from fasting level (positive unless otherwise indicated) in specified time after breakfast			Change from fasting level (positive unless otherwise indicated) in specified time after lunch			
		1 hour	2 hours	3 hours	1 hour	2 hours	3 hours	4 hours
Breakfast No. 1:								
CL	86	−2	−1	2	19	0	−5	−7
UR	88	3	−3	0	29	−9	−9	−9
WM	93	4	1	4	42	7	−7	−4
HL	96	−2	−3	1	40	16	−6	6
AD	97	−3	−7	−7	32	1	−8	−11
GE	101	−8	−8	−4	1	−7	------	−15
TG	117	−2	−5	−16	23	0	−21	−28
Average	97	−1	−4	−3	27	1	−9	−10
Breakfast No. 2:								
CL	83	23	9	6	44	3	7	−2
UR	91	19	−13	−5	37	−5	−12	−10
WM	99	40	−5	−7	34	8	−15	−13
HL	97	29	10	−5	15	12	−5	−12
AD	112	24	11	−3	20	0	0	−10
GE	88	10	5	7	27	7	3	−2
TG	130	8	15	−13	24	−15	−14	−25
Average	100	22	5	−3	29	1	−5	−11
Breakfast No. 3:								
CL	80	22	−7	−9	65	5	−2	9
UR	84	9	4	6	43	16	−2	8
WM	99	26	3	6	35	20	7	3
HL	115	−8	−16	−19	20	6	−16	−18
AD	86	26	7	7	27	4	5	2
GE	100	−10	−7	−14	12	−8	−14	−6
TG	106	16	−11	−20	14	−10	−7	−15
Average	96	12	−4	−6	31	5	−4	−2
Breakfast No. 8:								
CL	83	29	13	3	30	8	3	8
UR	83	26	7	13	19	9	8	13
WM	93	−7	13	11	34	13	12	4
HL	97	10	22	10	31	19	16	9
AD	96	21	8	5	13	------	6	−3
GE	102	12	−10	8	3	14	−8	−12
TG	119	12	4	−12	5	−17	−14	−11
Average	96	15	8	5	19	8	3	1

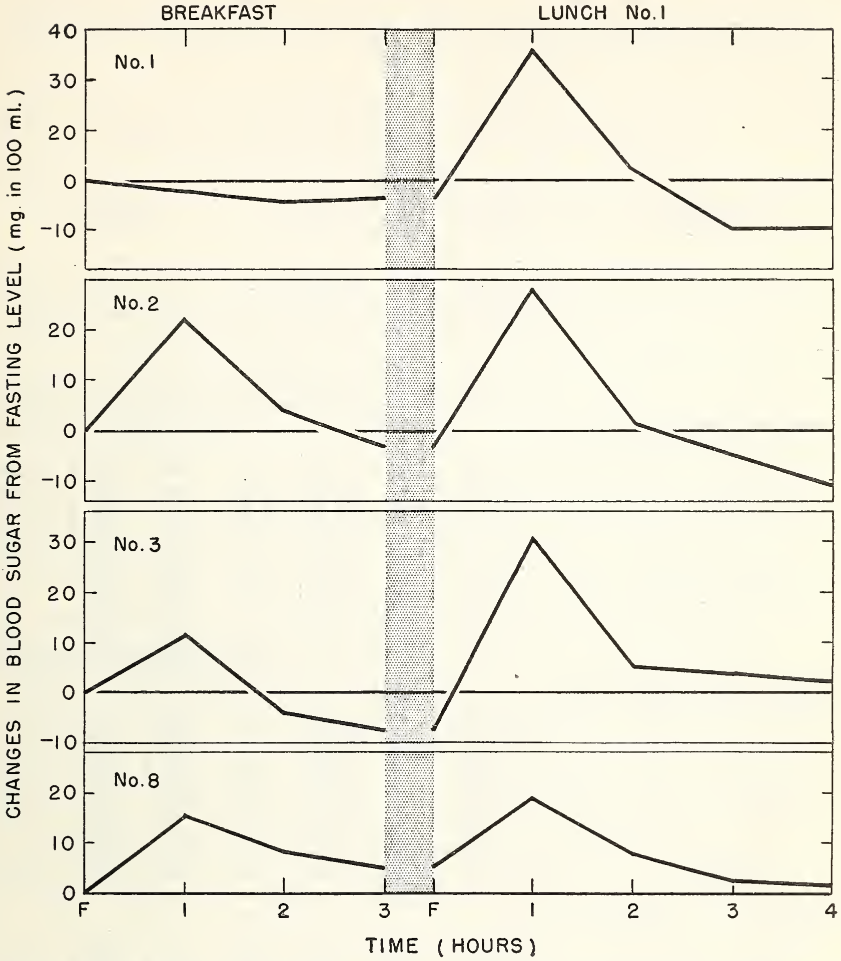

Figure 3.—Changes in blood sugar from fasting levels during 3 hours following ingestion of four experimental breakfasts, and in turn during 4 hours following the same luncheon.

TABLE 6.—*Average urinary excretion of creatinine, pyruvic acid, and thiamine following breakfasts and 2 types of luncheons and dinners (3 experimental periods per subject)*

Meal combinations and subject	Average quantity of specified constituents in urine found during stated intervals—						
	Creatinine	Pyruvic acid			Thiamine		
	0–24 hours	0–3 hours	3–24 hours	24–27 hours	0–3 hours	3–24 hours	24–27 hours
	Milligrams	*Milligrams*	*Milligrams*	*Milligrams*	*Micrograms*	*Micrograms*	*Micrograms*
Breakfast No. 1 plus lunch No. 1 and dinner No. 1:							
CL	1, 250	1. 8	9. 5	1. 7	83	209	28
UR	1, 239	3. 4	12. 1	2. 7	99	357	60
WM	1, 181	3. 3	10. 7	2. 7	65	161	54
HL	980	1. 3	12. 6	2. 6	44	281	56
AD	1, 245	1. 2	10. 9	4. 1	17	153	28
GE	941	2. 3	11. 2	2. 0	100	249	22
TG	1, 168	1. 5	7. 9	1. 6	26	223	48
Average	1, 145	2. 1	10. 7	2. 5	62	232	42
Breakfast No. 2 plus lunch No. 1 and dinner No. 1:							
CL	1, 413	3. 0	10. 0	2. 2	90	325	38
UR	999	2. 5	8. 8	2. 4	140	442	78
WM	1, 018	2. 6	8. 7	1. 9	55	132	50
HL	1, 057	2. 1	11. 9	2. 2	78	255	69
AD	1, 215	3. 6	10. 9	2. 9	34	124	28
TG	950	2. 6	6. 3	2. 5	45	127	48
Average	1, 109	2. 7	9. 5	2. 4	74	234	52
Breakfast No. 3 plus lunch No. 1 and dinner No. 1:							
CL	1, 275	2. 0	7. 6	2. 3	39	187	34
UR	1, 014	4. 7	9. 5	3. 7	85	209	65
WM	850	2. 6	5. 9	1. 9	63	134	54
HL	950	2. 0	9. 4	2. 9	93	263	88
AD	1, 366	3. 6	11. 9	3. 9	37	151	45
GE	1, 186	2. 4	9. 3	2. 1	37	139	32
Average	1, 114	2. 9	8. 9	2. 7	59	184	53
Breakfast No. 3 plus lunch No. 2 and dinner No. 2:							
CL	1, 156	2. 6	8. 8	2. 9	73	267	69
UR	1, 102	3. 1	8. 9	3. 0	96	411	98
WM	1, 014	1. 7	6. 3	1. 5	104	389	107
HL	1, 014	2. 5	7. 9	2. 7	99	425	106
AD	1, 295	3. 0	8. 6	2. 4	43	126	22
GE	1, 107	3. 2	8. 3	2. 1	63	159	46
Average	1, 115	2. 7	8. 1	2. 4	80	296	75

TABLE 6.—*Average urinary excretion of creatinine, pyruvic acid, and thiamine following breakfasts and 2 types of luncheons and dinners (3 experimental periods per subject)*—Continued

Meal combinations and subject	Average quantity of specified constituents in urine found during stated intervals—						
	Creatinine	Pyruvic acid			Thiamine		
	0–24 hours	0–3 hours	3–24 hours	24–27 hours	0–3 hours	3–24 hours	24–27 hours
	Milligrams	*Milligrams*	*Milligrams*	*Milligrams*	*Micrograms*	*Micrograms*	*Micrograms*
Breakfast No. 8 plus lunch No. 1 and dinner No. 1:							
CL	1, 107	1. 8	8. 2	1. 8	42	191	28
UR	1, 062	3. 9	8. 2	2. 6	82	149	58
WM	1, 051	2. 0	5. 6	1. 5	53	164	44
HL	1, 060	3. 2	11. 6	2. 9	98	323	91
AD	1, 167	2. 5	6. 9	2. 5	36	119	45
GE	1, 126	2. 0	9. 6	1. 8	40	186	34
Average	1, 095	2. 6	8. 4	2. 2	59	189	50
Breakfast No. 8 plus lunch No. 2 and dinner No. 2:							
CL	1, 273	2. 3	8. 2	1. 7	53	239	47
UR	1, 044	3. 3	8. 3	3. 9	50	306	107
WM	1, 274	2. 6	8. 7	1. 2	72	404	117
HL	1, 086	2. 8	9. 3	2. 0	94	488	149
AD	1, 380	2. 3	11. 1	2. 9	30	206	39
GE	1, 137	1. 9	8. 8	1. 8	63	275	46
Average	1, 199	2. 5	9. 1	2. 3	60	319	84

GENERAL OBSERVATIONS

Under the conditions of these experiments blood-sugar levels appeared to be a more sensitive indicator of physiological response to the different breakfasts served than did urinary excretion of thiamine or pyruvic acid.

With meals providing between 500 and 750 calories, sustained blood-sugar levels and a sense of well-being seems to be more related to the quantity and quality of the protein in the meal than to the carbohydrate or fat content. The favorable effect may be due to the relatively slower digestion, absorption, and metabolism of protein as compared with carbohydrate, and consequently to a steadier supply of glucose in the blood.

The food included in the general type of breakfast eaten by a group of laboratory workers over a period of 7 consecutive days is of interest, particularly the quantity of milk, eggs, or meat they consumed.

Only 11 percent of 68 Bureau employees had seven or more glasses of milk at breakfast during the course of a week, and 40 percent had none. About one-fifth had seven or more servings of meat or eggs for breakfast during the week, but 13 percent had none.

These findings and those for other food items analyzed by age of individual appear in table 7. The 50- to 68-year group drank milk at breakfast most frequently—28 percent had seven or more servings during the week, as compared with 10 percent of the 40- to 50-year group. The frequency of consumption of eggs or meats was about the same in all the age groups. Citrus fruits or juices or tomato juice were used daily by a considerable percentage in every group. The omission of bread or rolls, and sugar, preserves, and sirups was most frequent among the oldest age group. The great diversity of present-day breakfast habits shown in this small study is in line with that found by surveys made in various parts of the country (*2*, *17*, *18*, *23*, *27*, *35*).

TABLE 7.—*Frequency of food used at breakfast during 7 consecutive days by 68 individuals classified by age*

Age range (years)	Number of subjects	Food item	Percentage of breakfasts containing food item	Percentage of individuals using specified number of servings of food item in 7 days				
				None	1	2 or 3	4, 5, or 6	7 or more
20–29	16	Milk to drink	24	45	31	6	12	6
30–39	20		25	45	10	30	10	5
40–49	18		33	39	22	6	23	10
50–68	14		55	30	28	0	14	28
All	68		34	40	22	12	15	11
20–29	16	Egg or meat	54	13	0	44	18	25
30–39	20		50	15	5	25	35	20
40–49	18		46	17	0	44	23	16
50–68	14		60	9	14	7	49	21
All	68		52	13	4	31	31	21
20–29	16	Citrus fruit or tomato juice.	64	6	6	24	24	40
30–39	20		54	25	10	10	25	30
40–49	18		67	17	6	11	12	59
50–68	14		64	7	21	7	28	37
All	68		62	14	10	12	24	40
20–29	16	Breakfast cereal	20	50	20	18	6	6
30–39	20		14	50	20	25	5	0
40–49	18		21	50	20	12	12	6
50–68	14		28	58	0	14	14	14
All	68		20	52	16	17	9	6

TABLE 7.—*Frequency of food used at breakfast during 7 consecutive days by 68 individuals classified by age*—Continued

Age range (years)	Number of subjects	Food item	Percentage of breakfasts containing food item	Percentage of individuals using specified number of servings of food item in 7 days				
				None	1	2 or 3	4, 5, or 6	7 or more
20–29	16	Bread or rolls	68	12	0	18	25	45
30–39	20		76	5	0	15	5	75
40–49	18		86	0	0	12	12	76
50–68	14		61	21	7	0	21	51
All	68		74	9	1	12	15	63
20–29	16	Butter, other table fat, cream.	66	6	12	12	25	45
30–39	20		63	15	5	20	10	50
40–49	18		83	0	6	6	23	65
50–68	14		43	7	28	21	28	16
All	68		65	7	12	15	22	44
20–29	16	Sugar, preserves, sirups.	61	19	12	6	25	38
30–39	20		50	5	10	30	35	20
40–49	18		63	6	17	17	17	43
50–68	14		30	36	21	21	0	21
All	68		52	15	15	19	20	31

SUMMARY

Using six or seven adult women as subjects in each series, studies were made of the relation of different breakfast meals to blood-sugar concentration and urinary thiamine and pyruvic acid.

Included in the investigation were eight different food combinations that provided varying quantities of protein and food energy. One consisted of unsweetened black coffee only. A second, composed of unsweetened black coffee and doughnuts, furnished 7 gm. of protein and 400 calories. A third, made up of citrus juice, bacon, toast with butter and preserves, and coffee with cream and sugar, provided 9 gm. of protein and 360 calories. The other breakfasts consisted of the last-named combination with or without preserves and with the addition of (a) breakfast cereals and milk; (b) eggs; or (c) milk. The cereal-containing breakfasts afforded about 17 gm. of protein and somewhat more than 500 calories. The other three breakfasts provided from 22 to 25 gm. of protein and from about 500 to somewhat more than 750 calories.

During a 3-hour test period immediately following the morning meal, the subjects having only unsweetened black coffee experienced a progressive fall in blood sugar below the fasting level. At no time did the values fall to true hypoglycemic levels, but traces of acetone were detected in the urine of three out of the seven subjects and unfavorable subjective symptoms, including hunger, weakness, headache, and lassitude were often reported.

Blood-sugar curves following ingestion of breakfasts that provided 7 to 17 gm. of protein and 360 to 520 calories were characterized by a rapid rise from the fasting level during the first half hour, followed by a fall to the original fasting level during the next 3 hours.

After breakfasts that provided 22 gm. of protein derived chiefly from milk or eggs and about 500 calories, the postprandial rise in blood sugar was normal, but the average maximal figure was lower and the return to the fasting level delayed beyond that characteristic of the isocaloric breakfasts of lower protein content. A sense of well-being was consistently reported following the breakfasts that provided the larger quantities of protein-rich food.

It was further found that the breakfast meal may influence blood-sugar levels during the afternoon. Following an identical midday meal of sandwich and coffee, a lower maximal rise in blood sugar was observed together with a relatively more sustained sugar level during the course of the afternoon, when subjects had eaten a breakfast providing 25 gm. of protein and about 750 calories, in contrast with breakfasts providing less than 10 gm. of protein and 400 calories. Subjective symptoms of hypoglycemia were also reported after lunch when only unsweetened black coffee was taken for breakfast. These symptoms accompanied a rapid drop in postluncheon blood-sugar levels.

During the course of the 2-year experimentation, highly significant seasonal differences were found in the fasting blood-sugar levels. Although within the range generally considered normal, the figures for the individuals studied tended to be higher in the winter than during the summer months.

Under the conditions of the experiments reported in this publication blood-sugar levels appear to be a more sensitive indicator of physiological response to different breakfast meals than urinary excretion of thiamine or pyruvic acid.

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